A COMPARATIVE ANALYSIS OF TAPE RECORDING TECHNOLOGIES FOR MID-RANGE SYSTEMS AND SERVER APPLICATIONS

Emerging Markets - Characteristics and Requirements

Today's emerging digital applications, such as document imaging and digital content, have joined more traditional storage applications geared toward data protection and archiving to drive the need for higher capacity, faster, and more durable tape-based solutions. Customers want solutions that maximize available space, minimize power consumption and other operating costs, shorten recording times, run without manual intervention, and offer the highest levels of reliability. For automation applications, where tape is used because it costs the least per terabyte of storage, customers need solutions that permit fast time-to-data to their vast amount of stored information, as well as confidence in the ability to access and retrieve the information later. This paper highlights the storage requirements of digital applications in mid-range system and server environments and describes the essential tape technology characteristics needed to satisfy these needs.

Overview of Recording Technologies for Tape

Midrange platforms employ one of two tape recording technologies: helical-scan or linear serpentine. Each is characterized by the methods in which it draws the tape across the recording head, records information onto a tape reel, and also how that recorded information is configured on the tape.

Helical-scan recording is a process in which the tape and the write head meet each other at a certain angle so that the data is recorded as diagonal stripes in one single forward pass. The read/write heads are mounted on a drum that rotates at a high speed, while the tape is pulled and moves slowly and gently across the spinning heads. The rotating drum/head is able to achieve the head/tape velocity needed to record data accurately and with higher track and linear bit densities compared to longitudinal methods.

The helical-scan technique was originally developed for video recording, as with VCRs, where data density was the primary concern. Sony Corporation was responsible for translating the technology to the data storage world. It recognized that with helical-scan recording it could actualize both high-capacity and physically compact solutions. Not only are helical-scan tape cartridges capable of storing large amounts of data, they are typically inches smaller than their linear-based counterparts and their data transfer rates are higher. An efficient packing density, low tape tension and tape speeds, as well as the ability to write multiple tracks simultaneously characterize helical-scan recording tape technologies. What’s more, helical-scan-based tape cartridges, such as AIT and Mammoth, are mounted at the center of the tape’s length. This eliminates the need to completely rewind the tape and reduces the time it takes to shuttle back and forth to locate a single file.

Linear serpentine recording technologies, on the other hand, feature read/write heads that remain stationary while the data is written to tracks running along the length of the moving tape. After one track is fully written, the head drops to the next track and writes in the opposite direction. Because linear technologies require many back-and-forth transversals of the tape (called serpentine recording for the S-shaped path it creates) to completely record the contents of the media cartridge, the process consumes a great deal of power and data access rates are slower because the tape must be completely rewound. Linear recording is also known to have low recording densities that require large amounts of media. And, because of the large amount of media required to store data at a competitive capacity point, linear technologies require large, single-reel tape cartridges that result in longer media load and unload times, as well as complex and potentially problematic media threading and unthreading operation. In its favor, additional head channels can be added to linear recording drives to boost data throughput.

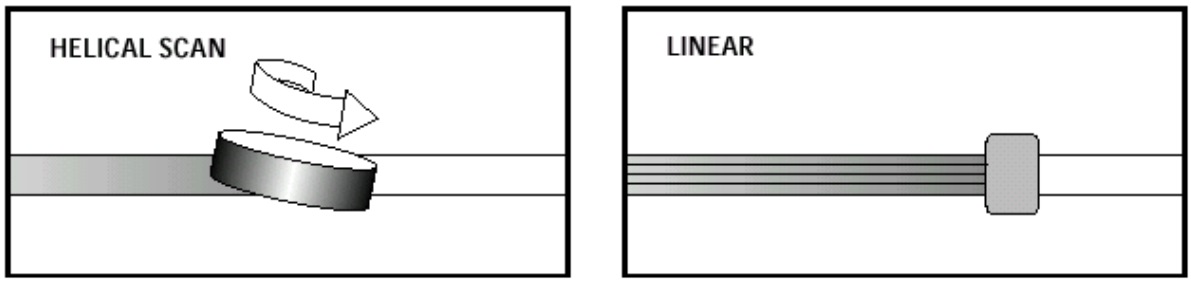

Figure 1: *Helical Scan and Linear Recording Methods*

Selection Criteria

Organizations choosing tape products for mid-range systems and servers have to consider capacity, performance, durability, and cost of ownership, and prioritize these for specific applications. Total cost of ownership, which is derived from these characteristics, together with overall space and power needs, is a key criterion across all applications because it directly impacts the cost of doing business. Questions to ask when evaluating a tape format for mid-range level storage include: What types of data or files am I storing? On average, how much storage capacity does my company consume every day? How much data do I expect to be storing five and ten years from now? How crucial are the files I store to my business? How quickly do I need to recall this data? Do I need to access this data on a daily basis or less frequently? How long do I want to, or have to, keep this data available? How much am I paying per megabyte of storage?

The answers to questions like these can help a storage administrator derive ownership figures that map into storage goals for their business. They are also valuable for pinpointing the tape storage format that best suits the speed, capacity and scalability characteristics most apt for a particular business or IT architecture.

Tape Recording Density and Capacity

In unattended backup, image/data storage and archival applications, large amounts of data are written once and read infrequently. In this typically automated environment, total stored capacity potential is a critical solution characteristic, providing both functional and cost benefits. Small-sized, high-capacity tapes reduce the total number of automation units required, as well as the physical space and power needed to support them. Higher capacity also allows more data to be "online" for a given number of drives and, in many cases, tape data density and capacity can determine whether additional tape libraries are required for the application, which can impact limited floor space, power usage demands, and overall support costs.

Helical-scan technology is uniquely qualified to meet the space and power limitations experienced today at many customer sites. For example, Sony's AIT-3 holds over four times the data density of the nearest linear tape competitor, while occupying less than one half of the drive and media size. This margin of capacity advantage will increase dramatically with the planned introduction of the next generation of AIT technology, S-AIT, which will offer over five times more capacity than competing technologies.

Model Name	**AIT-1**	**AIT-2**	**AIT-3**	**M2**	**DLT8000**	**LTO**	**SDLT**
Technology	Helical	Helical	Helical	Helical	Linear	Linear	Linear
Linear Recording Density	116 Kbpi	167 Kbpi	155Kbpi	165 Kbpi	98Kbpi	131Kbpi (approx)	133
Areal Density Mbits/Sq. inch	268	385	716	342	40	100	119

Table 1: Relative Density of Helical Scan vs. Linear Products

Helical-scan product capacities result from a much larger track density (up to 5 times greater) and constitute more efficient recording of the media than linear serpentine recorded tapes. The large recording density and space efficient design allow helical-scan products to be much smaller than typical linear technlogies at a given capacity point.

Performance

Any sophisticated data management software package can transparently migrate data between fixed media, such as disk drives, to near-line removable media, based on application and user file access frequency. Overall tape sub-system performance is crucial in this write once, read many times environment. Unlike typical, sequential backup or archival applications, these near-line software solutions frequently access stored data on tape, and access performance is a key competitive metric.

Higher data transfer rates, together with fast media load and file search speeds, are needed to provide a total performance solution – a critical need for corporations as they commit more and more information to automated systems. Improved time-to-data also enables faster response to data restore requests and could slash hours off the restore times of customer files when compared to linear technologies. Helical-scan recording is inherently a high-performance technology due to its much shorter media length requirements and sequential (non-serpentine) recording. As a result, helical recording can

easily outperform competing linear products in “total access” to data by a margin of two to one or more.

In addition to minimizing total time to data, helical-scan frequently provides higher data transfer rates due to better head-to-tape velocity, achieved through the use of a spinning drum or scanner element. This element houses the various read and write heads and can easily be configured with more head elements to further improve the data transfer rates necessary for today’s applications. Although linear serpentine products can also add more recording head elements, this type of configuration becomes more mechanically complex and costly than helical-scan technology.

Memory-In-Cassette

Sony has improved upon the inherent data access benefits of helical-scan recording by incorporating an innovative semiconductor memory element (Memory-in-Cassette, or MIC) within its AIT-1 and AIT-2 media cartridges and libraries. The MIC consists of a memory chip built into the data cartridge that speeds access to files and cartridge data and holds the system's log and other user-definable information. Applications that benefit from MIC's capabilities include hierarchical storage management, video server, film editing, and real-time data acquisition.

Sony’s AIT-3 and S-AIT technology incorporate Remote-MIC (R-MIC), which allows users to quickly access the same data without loading the cartridge. With R-MIC, users can access valuable tape cartridge data without rewinding or physically handling the tape, so it reduces the wear and tear on the tape. R-MIC also provides a direct and immediate connection to the AIT drive or library's on-board processors to enable quick media load, multiple on-tape load and unload points, and a wealth of data about the history and current state of the data cartridge. These technologies further expand the overall margin of helical-scan’s advantage in access performance over linear-recording techniques. The AIT approach records format information and file search parameters within the innovative MIC system, rather than using on-tape index files or requiring the time-consuming media load and tape threading process characteristic of linear technologies. This feature effectively cuts the data access time in half—regardless of tape drive speed and recording density.

Helical-scan optimizes application performance over a wide range of host data rates because of its very short “streaming re-cycle” time—enabled by the slow tape motion of helical-scan technology. In contrast, linear technologies have a large mass of media in high-speed motion that needs to be slowed down, then reversed and slowed down again to await data. Also, linear technologies need to “serpentine” back and forth for some portion of their file search, since data is recorded on tape with hundreds of tracks in a back-and-forth motion rather than a single forward pass. The short re-cycle time of helical-scan, together with its one-pass recording nature, allows for a much faster access to customer data.

In addition, if there is an overall data rate mismatch, linear mechanisms must go through a tremendous deceleration and acceleration of the high-speed tape motion. The time required to stop and re-synch can degrade performance noticeably in a random access environment, such as with automation applications. Helical-scan repositioning time is much faster because of the lower tape speed and quantity of media, and can outperform a higher data-rate linear drive in this environment.

Over time, demands for increased performance will be just as strong as those for tape capacity. Helical-scan products will meet those demands by continuing to expand the number of data channels written to tape simultaneously. For example, Sony's next-generation AIT product, S-AIT, will deliver significantly higher data transfer rates by recording and reading four channels simultaneously. As a proof in point, the products with the highest data transfer rates on the market today are helical-scan, such as Sony's DIR-1000 and DTF families.

Durability and Reliability

In the past, when tape was used primarily for backup and archival, tape drives were busy reading and writing only about 10 to 20 percent of the time that they were powered on. Early linear and helical-scan drives and their costs reflected this low duty-cycle environment. Today's high duty-cycle automation solutions, which are far more complex than these traditional single-drive applications, place a much heavier demand on drives and media. In a fully configured tape automation system, it is not unusual for tape drive utilization to approach 100 percent.

To support this very high utilization, significantly more durable tape drive designs are essential. The characteristics of helical-scan, with its gentle tape motion, air bearing tape wrap and very low tension, together with the exceptional durability of Advanced Metal Evaporated (AME) media used in helical-scan drives, make it ideal for this technology to achieve the durability standards required in high duty-cycle applications. The unique geometry of the recording head design allows for a very gradual wear profile that promotes exceptional head life and media life.

Conversely, with linear serpentine recording the tape undergoes much greater tension, travels at very high speeds over the stationary heads and requires several hundred back-and-forth traverses to complete a full recording of tape. This high-speed "shoe shining" process results in considerable wear of the media and recording heads, and also requires significantly more power dissipation toissipation to move, stop and reverse tape motion at those high speeds. In addition, during the serpentine reversal cycle at the end of each of several hundred passes, the linear mechanism introduces several seconds of data transfer delay, further impacting overall performance in a high-demand environment. Helical-scan, on the other hand, has no such delay since it is continously-moving tape in a single direction.

Cost of Ownership Benefits - Power Consumtion

Helical-scan's more cost-effective design, lower power consumption, smaller form-factor, and durable recording heads and media life translate directly into cost of ownership benefits. Within a 5.25-inch full height form-factor typical of the current linear products, a helical-scan mechanism, such as an AIT autoloader, can provide over four times the capacity, minimal downtime, and perform at levels exceeding that of comparable linear products.

Power consumption is another important attribute to consider in choosing a tape technology in today's limited and more costly power environment. Helical-scan products typically consume one-half to one-third the power required for linear technologies, and can thereby not only save subtantial operating costs, but can also more easily meet today's power conservation requirements. This is particularly important when considering multidrive automation solutions that can contain anywhere from six to over 20 drives per library.

This multiplication factor is even more compelling for projects requiring multiple libraries, as illustrated in Figure 2. The total cost savings of helical-scan products, including purchase price, as well as power consumption and reduced system downtime, make helical-scan a good business decision in all applications, and particularly essential in high duty-cycle applications, such as tape automation.

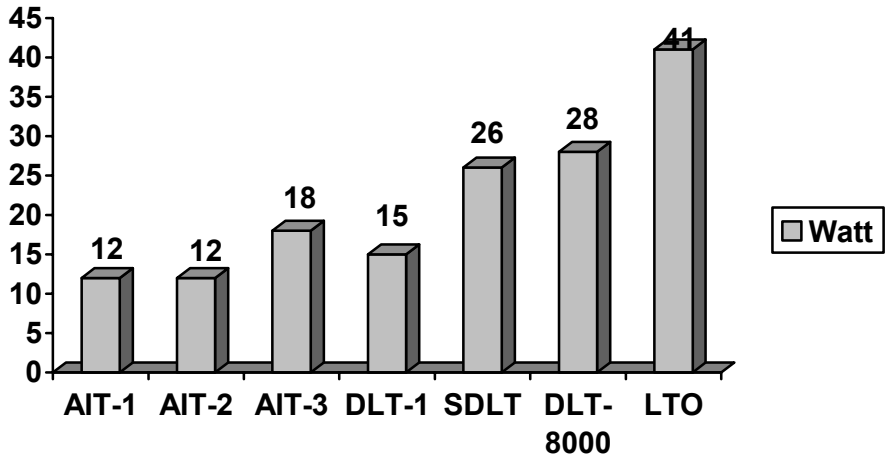

Figure 2: Power Consumption Comparison of Linear vs. Helical-Scan Library Automation Solutions

Summary

Inherent data density, access, data transfer performance, as well as reliability and durability characteristics, ideally position helical-scan tape technology to satisfy the current and future demands of backup and restore, image storage and retrieval, and other emerging removable data storage applications. Helical-scan recording provides very high data density and capacity today and offers the potential for significant improvements in future products to meet projected market needs.

Helical-scan products, with their typical dual-reel cartridge designs, also provide unmatched time-to-data to meet the requirements of high duty-cycle tape automation environments. All of these factors contribute to a cost of ownership advantage that lowers the cost of doing business for resource-constrained customers faced with limited space and power availability.

Sony is committed to maintaining this technology leadership with new and enhanced AIT products based on helical-scan recording. The roadmap of current and future AIT products, shown in Figure 3, demonstrates this commitment. With these compatible AIT drives, OEM library, and other stand-alone drive solutions, organizations can grow their tape capabilities as needed. With AIT, they have the highest capacity, most reliable and cost effective solutions available which address real-world constraints of space and power, as well as minimize the cost of ownership of the total solution.